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L. O. HOWARD, Chief

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THE BEET LEAF-BEETLE.[1]

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INTRODUCTION.

In the Rocky Mountain States sugar beets are subject to attack by the beet leaf-beetle, known in some localities as the "alkali bug," and in others as the "French bug." The principal injury caused is due to the attack of the larvæ, although the beetles also inflict considerable damage, hundreds frequently being found on a single plant, which is entirely consumed or so injured that it shrivels and dies. (See Pl. I.)

Injurious attack first attracted attention during 1897 and 1898, when injuries were noted both in New Mexico and Colorado. Prior to that time this insect was not known to injure cultivated plants, having confined its attack to such weeds or wild plants as the sea-blites, Russian thistle, and saltbush.

DESCRIPTION.

THE ADULT.

This insect is related to the imported elm leaf-beetle,[3] and is of similar appearance to that species in the larval, pupal, and adult stages, but it is considerably larger, and the beetle has a longer thorax, and is differently marked.

[1] *Monoxia puncticollis* Say.; order Coleoptera, family Chrysomelidae.
[2] Deceased.
[3] *Galerucella luteola* Müll.

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The beetle is variable in color and especially in markings, and in size, the length being from one-fourth to one-third inch. It is of oblong form, narrowing in front, and the color varies from pale yellow or buff to nearly black, while the elytra or wing-covers are uniformly yellowish or darker, but usually more or less distinctly striped with black. The beet-feeding form most commonly found is illustrated in figure 1, *a*.

The technical description by Dr. Geo. H. Horn (*4*)[4] follows:

THE GENUS MONOXIA LEC.

Head oval, moderately convex, not deeply inserted, front feebly or not impressed. Antennæ filiform, not longer than half the body, third joint as long as the first, fourth longer than the second, joints 6–10 subequal in length; labrum moderately prominent, truncate with rounded angles; maxillary palpi moderately stout, second and third joints obconical, the terminal conical and more slender; prothorax transverse, widest at base, except in *sordida;* scutellum oval at tip; elytra oblong, scarcely broader behind the humeri, closely and irregularly punctured, the side margin not prominent; epipleuræ narrow, but extending nearly to the tips of the elytra; prosternum entirely obliterated between the coxæ, the coxal cavities open behind. Legs moderate, the anterior tibiæ indistinctly grooved on the outer side, tibiæ without terminal spurs; tarsi shorter than the tibiæ, the first joint as long as the next two; claws dissimilar in the sexes, finely bifid in the male, absolutely simple in the female.

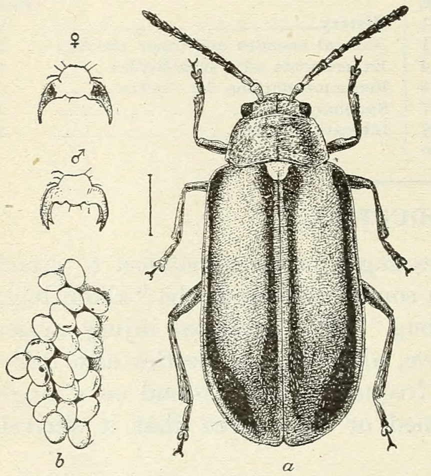

FIG. 1.—Western beet leaf-beetle (*Monoxia puncticollis*): *a*, beetle; *b*, eggs; ♀, claws of legs of female; ♂, ditto of male. *a*, much enlarged, *b*, more enlarged. ♀ ♂ highly magnified.

MONOXIA PUNCTICOLLIS Say.

Form oblong, narrowed in front; surface finely pubescent, color variable from pale yellow to entirely black, or with the elytra vittate. Antennæ variable in color from entirely black to pale, generally with the outer half dark, the base pale, fifth joint always shorter than the fourth or sixth. Head coarsely and closely punctate. Thorax not quite twice as wide at base as long at middle, broader at base than apex, sides freely arcuate, base broadly emarginate at middle, oblique each side, hind angles distinct; disc usually irregular, with broad, vague depressions each side, so that at times the sides of the thorax appear deplanate, a vague median impressed line, surface very coarsely and irregularly punctate; elytra closely punctate and finely pubescent, the punctures coarser near the base, fine and closer toward the sides and apex. Body beneath finely sparsely punctate and pubescent. Length .27–.34 inches; 7–8.5 mm.

Male. Claws [fig. 1, ♂] finely bifid at tip; last ventral segment obtuse, with a short median linear impression near the apex.

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[4] Figures (italic) in parenthesis refer to "Literature cited," p. 23.

Female. Claws [fig. 1, ♀] absolutely simple; last ventral obtuse, with a small notch at middle, from which proceeds a slight impression or a smooth line. (Horn).

SYNONYMY.

The following forms are considered synonyms:
Galeruca morosa Lec., Rept. Pac. R. R. Expl., p. 70.
Galeruca maritima Lec., Proc. Acad. Nat. Sci. Phila., 1865, p. 218, 219.
Galeruca erosa Lec., Trans. Amer. Ent. Soc., v. 12, 1885, p. 25.

THE EGG.

The egg (fig. 1, *b*) is variable rounded oval in shape, light orange yellow when first laid, changing to dull brownish gray; strongly convex above and moderately flattened on the underside where attached to a leaf. The surface is minutely and deeply reticulated or pitted, a septagonal arrangement predominating, although hexagons also occur. The length is 0.8–0.9 mm. and the width 0.6–0.7 mm.

The eggs are deposited side by side, usually on end, and closely together in irregular clusters—not infrequently in two layers, some laid on top of others—varying in number from 2 or 3 to 50, with an average of about 20 eggs in each cluster. They are laid on either the upper or lower side of the leaves of beets and more often on other larval food plants. (See Pl. II.)

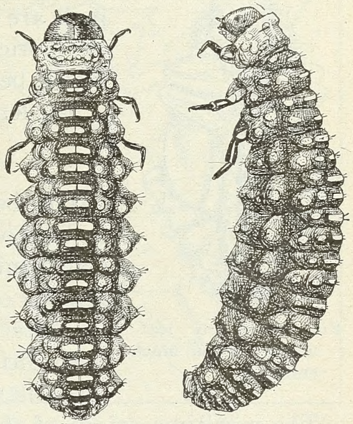


FIG. 2.—Beet leaf-beetle: Dorsal view of larva at left; profile view at right. Highly magnified.

THE YOUNG LARVA.

The young larva when hatched measures about 1.5 mm. and differs from the mature form in having a more prominent head, a dark brown thoracic plate on shield, and in being of a dull gray color, the tuberculate areas being less conspicuous, showing as darker brown. The legs are relatively more prominent and the hairs or spines with which the tubercles are armed are longer.

THE MATURE LARVA.

The mature larva (fig. 2) resembles in general contour, both as seen from above and from the side, that of Galerucella. It is nearly uniform dark olive brown in color, spotted with piliferous tubercles, which are more or less rounded, rather pale yellow and strongly marked. They are arranged in somewhat irregular rows, as shown in the illustration, those on the dorsal surface of the abdominal segments coalescing near their centers, forming transverse bands. The head is moderately shining black and portions of the legs are

of the same color. The hairs with which the body is very sparsely clothed are of two kinds, pointed and truncate, some being pale and some dark in color, all being rather short. The head is about half as wide as the first thoracic segment and the body gradually widens to the third and fourth abdominal segments, and then tapers gradually toward the anal extremity, and the last segment is rather narrow. The segmentation is strongly marked and the tubercles on the sides prominent. The legs are long and somewhat slender.

The length in somewhat contracted natural position is about 8.5–9.03 mm. and the greatest width 2.8–3 mm.

THE PUPA.

The pupa (fig. 3) is of the usual chrysomelid form, nearly twice as long as wide, pale yellowish in color, the head prominent, bent downward on the thorax, with the legs folded so that the tarsi are in a nearly parallel line. The wing-pads are rather long and the abdominal segments are noticeable for the lateral processes, each of which bears a short spine-like hair.

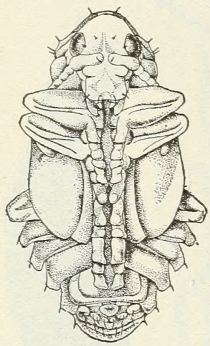


FIG. 3.—Beet leaf-beetle: Pupa, much enlarged.

The length is 6.5–8 mm. and the width 3.5–4 mm.

DISTRIBUTION.

The beet leaf-beetle occurs along the Atlantic seaboard from Massachusetts to Florida, in California near the seacoast, and in the alkaline regions of Colorado, Utah, and New Mexico. In its eastern occurrence it is maritime, being found very little inland from the States mentioned. The distribution is shown in the map, figure 4.

The maritime origin of the species is evidenced by its occurrence in the East along the entire Atlantic coast from New England to the Gulf of Mexico. It is seldom, if ever, found far inland in that region. In the West it occurs in California near the seacoast and also in the alkaline regions of Arizona, New Mexico, Colorado, Utah, and Montana. In its distribution it resembles *Cicindela lepida* Dej., a white form of tiger beetle inhabiting the alkaline or saline, white, sandy soil left by the recession of the sea water which formerly covered this region. The writer is inclined to believe that the coastal forms are at least subspecies or races and that a third form which occurs in Florida, in Kansas, and in southern Texas constitutes still another subspecies.

A single adult of this species was collected at Wichita, Kans., April 24, 1917, by Mr. F. M. Wadley, Bureau of Entomology. It is of the normally injurious form and it is not improbable that the species may have a somewhat general distribution in Kansas, but it

must be somewhat local as regards abundance; in other words, what we commonly term rare.

Only the so-considered subspecies or normal type occurring in the Middle West from Arizona and New Mexico to Montana is destructive to sugar beet, although in one instance report of attack to beets at Brownsville, Tex., was noted. While the localities indicated on the map show injuries only in six States, it is readily seen that injury is apt to take place in neighboring States; e. g., Wyoming, western Nebraska, Kansas, Oklahoma, and Texas, and perhaps eastern Nevada. From what is known of this species it seems probable that it is not one of the numerous pests which are constantly on the increase and which are enlarging their injurious distribution, but, on

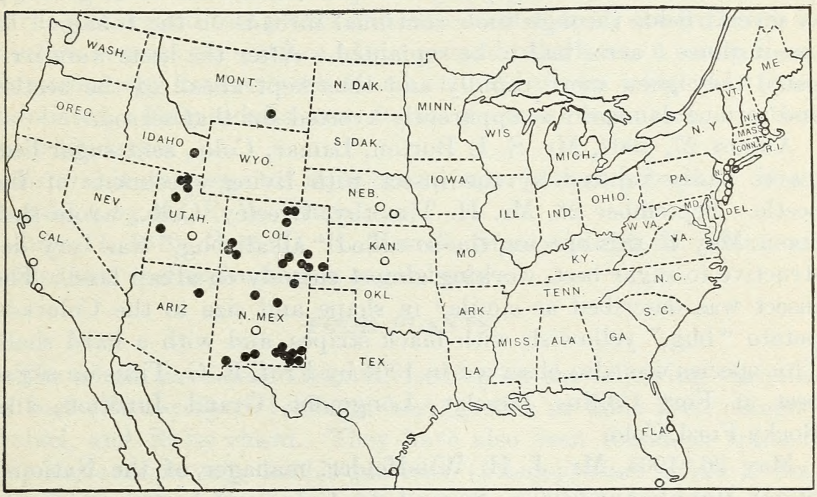


FIG. 4.—Map showing distribution of beet leaf-beetle. Large dots show injurious distribution; circles, innoxious localities.

the contrary, it may, in the course of time, especially if remedial measures are adopted, rather decrease its injurious range than otherwise, or at least decrease as a pest.

REPORTS OF INJURIES.

Under date of January 4, 1898, Mr. Henry C. Barron, Hagerman, N. Mex., sent specimens of the beet leaf-beetle with statement that it was doing serious injury to the sugar-beet crop in that locality. Its presence was not noticed until the year 1897. A few of the beetles, locally known as "French bugs," were found at that time by digging in the earth by the side of a beet to the depth of about 6 inches. Neither eggs nor larvæ were to be found at this time. The correspondent stated that the beetles lay their eggs on the underside of a leaf, that they hatch in about 6 days, and that the young larvæ commence feeding at once and continue for 9 or 10 days, when they

dig their way into the ground and a few days later come forth as beetles. The principal damage it was noted was due to the larvæ, hundreds of which often occurred on a single plant, which was either consumed or apparently so injured that it shriveled and died.

During 1902 and 1903 this species was reported injurious to sugar beets by Mr. W. K. Winterhalter, Rocky Ford, Colo. May 7, 1902, he wrote that where the beetles had appeared they kept the leaves eaten down to such an extent that the beet was unable to make any growth. They were most numerous on very warm, loose land, rich in lime, and a rapid increase under the then favorable climatic conditions was anticipated. They were gregarious, occurring "in swarms like blister beetles." Later it was reported that while the beetles had not done extensive damage, they had prevented beets from growing in several fields through their continual inroads on the foliage. In one instance 5 acres had to be replanted. After the beets were irrigated they grew more rapidly and thus kept ahead of the beetles and serious damage was apparently averted for that season.

August 27, 1904, Mr. S. I. Borton, Lamar, Colo., sent sugar-beet leaves badly injured by the insect with living specimens of the beetle. September 26, Mr. H. Timothy, Greeley, Colo., wrote that about May 15 this species, the so-called "alkali bug," was very destructive to sugar beet, working almost entirely on alkali land. The insect was described as similar in shape and size to the Colorado potato "bug," yellowish with black stripes, and with a hard shell. This species was also observed in 1904 by Prof. E. G. Titus on sugar beet at Fort Collins, Greeley, Longmont, Grand Junction, and Rocky Ford, Colo.

May 26, 1905, Mr. J. H. Windfelder, manager of the National Sugar Manufacturing Co., Sugar City, Colo., sent beetles and larvæ observed on young sugar beet. They proved very destructive, destroying the young beets down to the ground. They were found in an area that was somewhat seepy or wet, and, although they spread beyond this area, they did the most damage adjacent thereto.

June 30, 1909, Mr. Harry B. Shaw, at that time engaged in sugar-beet investigations for the Bureau of Plant Industry, sent specimens collected on sugar beet at Thatcher, Utah, growing on the margin of fields close to alkaline ground in which grew "salt-grass" (*Atriplex* sp.) and some other weeds. At that time the insects were migrating to the beets and eating them to the ground, although the beets were then of considerable size. This species was also reported by Mr. Shaw attacking beets and Dondia at Garland, Utah, August 15.

June 14, 1910, injury was reported to young beets at Manzanola, Colo., by Mr. W. W. Spencer. He found it in beets growing near sloughs and a considerable number on lamb's-quarters.

July 5, 1910, numerous adults and egg clusters were observed by Mr. D. K. McMillan in a beet field a mile southwest of Rocky Ford, Colo. They were also working on Russian thistle growing along a ditch, together with larvæ about a week old. This locality is near a large "alkali spot" caused by seepage. Adults were very abundant there the previous fall and many came through the winter under rubbish. During the week following, beet leaves were considerably eaten around the edges by the beetles. The species, it was surmised, would be likely to cause considerable damage in the field at this point during the next few weeks if it were not checked by spraying. August 9 Mr. McMillan reported all stages very numerous in the alkali flat 2 miles south of town on weeds along the roadside and on sugar beets at Rocky Ford, Colo. Pupæ were not difficult to find in the soil around beet plants and were located from one-half inch to 2 inches beneath the surface of the ground, which was a sandy loam. Numerous egg masses were found on wild plants which had been defoliated. Fifty adults were found on some plants and on others fully 100 larvæ.

In 1913 it was reported injurious to sugar beet at Artesia, N. Mex., August 4, by Mr. R. W. Bruce.

July 17, 1916, Prof. D. E. Merrill, State College, N. Mex., reported this species feeding on sugar beets.

FOOD PLANTS.

The adults have been observed feeding on the following varieties of beet (*Beta vulgaris*): Sugar beet, garden or table beet, mangel-wurzel, and Swiss chard. They have also been found on spinach (*Spinacia oleracea*), lamb's-quarters (*Chenopodium album*), sea-blite (*Dondia erecta*, *americana*, *linearis*, *multiflora*, and *depressa*), Russian thistle (*Salsola pestifer*), saltwort (*S. kali*), saltbush (*Atriplex argentea*, *patula*, and *hastata*), sea purslane (*Sesuvium sessile*) and pigweed (*Amaranthus retroflexus*). Some of these host plants are shown in Plates II to V.

Lamb's-quarters, sea-blite, and sugar beet are the favorite food plants of the beetle; Russian thistle and sea purslane are readily eaten in early spring when other food is comparatively scarce, but table beets, mangel-wurzel, spinach, and Swiss chard are more rarely injured, although relished by the beetles which occur on them by chance infestation. Salt-bush and pigweed are less popular and seldom attacked.

The larvæ are still more restricted in their choice of food. They have been observed feeding on sea-blite, lamb's-quarters, Russian thistle, and sugar beet. Sea-blite (Pl. VI, D), and lamb's-quarters (Pl. VI, C) are decidedly the favorites and are eaten in preference to all other plants. Sea-blite occurs in densely growing areas and by

far the greatest number of larvæ usually develop on it. Large areas of this plant, acres in extent, are often killed by the insects. The dead plants turn black and, at a distance, appear as though injured by fire. The spikelike leaves of young Russian thistle are eaten by the larvæ but are not a favorite food. While large numbers of larvæ frequently develop on sugar beet, this happens as a general rule only in the event of a scarcity of the favorite natural food plants. Larvæ are sometimes so abundant on sea-blite and lamb's-quarters about the margins of beet fields that the plants are killed (Pl. VI, C, D) and become dry, causing the partly-grown larvæ to crawl into the beet fields and complete their development on the beets.

Eggs are occasionally deposited on sea purslane and on some other weeds, but the larvæ have not been observed developing on these plants.

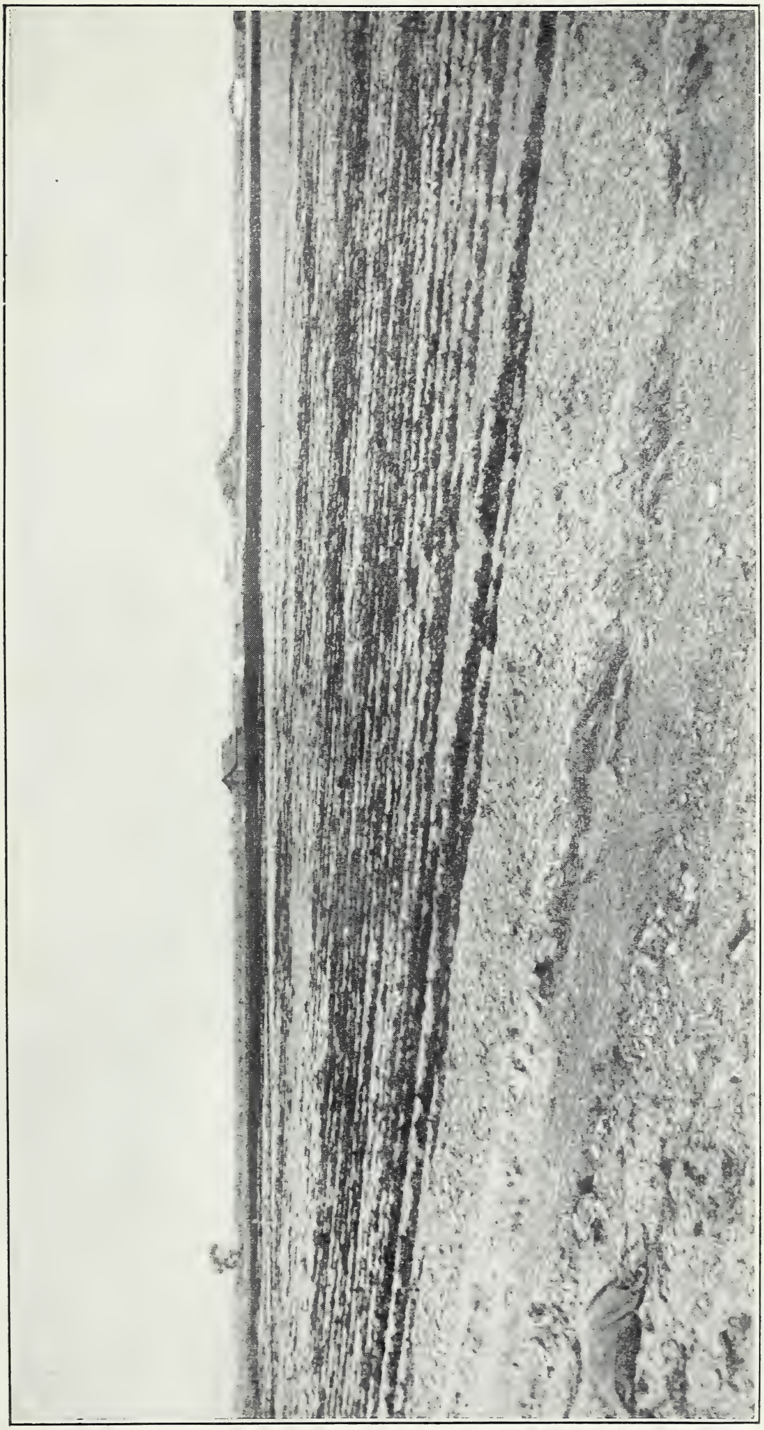
OCCURRENCE AND EXTENT OF INJURY.

The beet leaf-beetle, under natural conditions, lives upon weeds growing on land which, in many cases, is too highly charged with alkali to support cultivated crops. This waste land occurs throughout the upper Arkansas Valley in Colorado in low portions where excessive quantities of alkali have accumulated through natural drainage or by seepage from the irrigation ditches. These alkali areas vary in extent from a few square rods to many acres. Some of the alkali land has been partially or wholly reclaimed by tile drainage and, in many cases, the worst alkali spots adjoin or are surrounded by highly cultivated land. (See Pls. IV, V.)

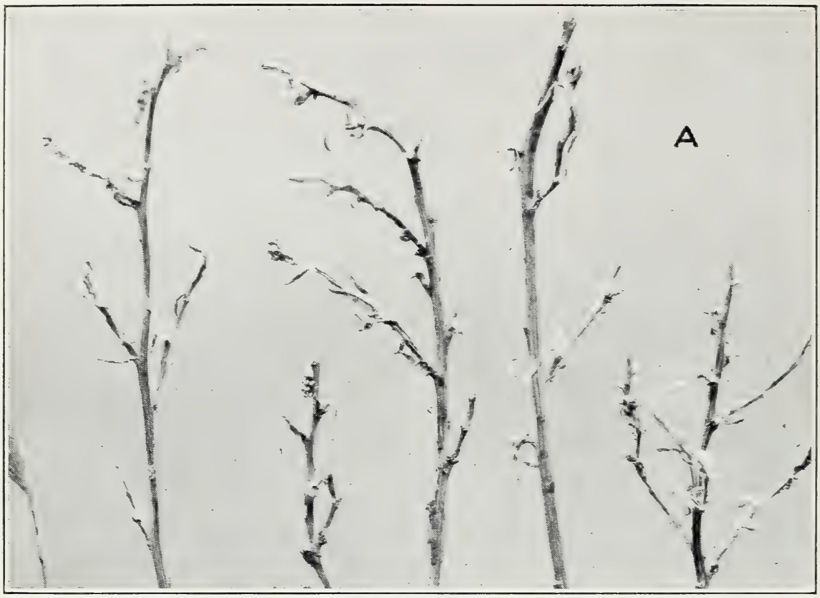
Sugar beets and sorghum, being particularly resistant to alkali, are frequently grown on land which is too "salty" to produce profitable crops of less resistant plants. Sorghum is not injured but the foliage of sugar beet is well liked by the beetles, and when this crop is grown on or near the alkali areas it is frequently severely damaged.

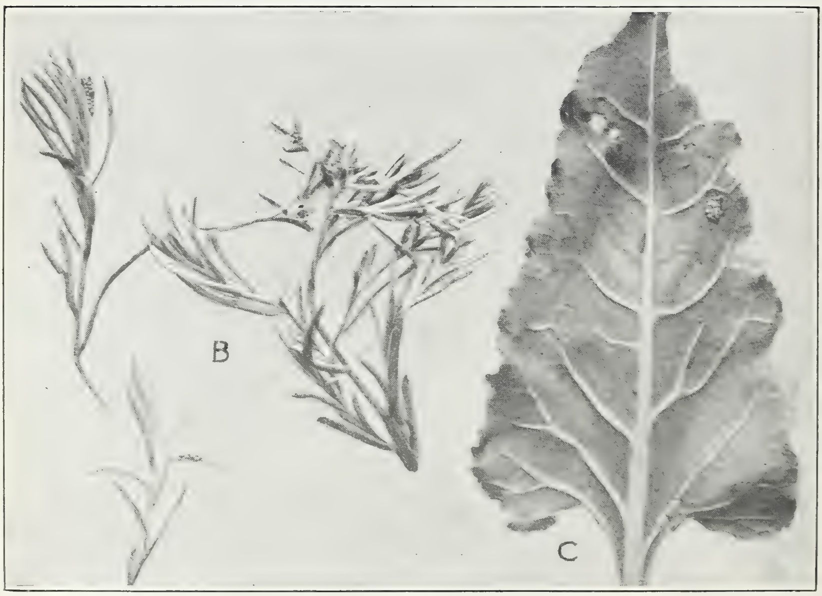
As long as there is a supply of the natural food plants available little damage is done to sugar beets. In the spring, before the weeds become abundant, the overwintered beetles, and more rarely the larvæ, may infest small, young beets and completely destroy them. Later the insects may develop in such enormous numbers that many of the weeds are killed and they may then resort to sugar beets for food. Many hundreds of acres of beets are infested every year. (See Pl. I.)

The injury resulting from infestation varies greatly, depending upon the abundance of the insects and the size of the infested beets. Small beets may be completely destroyed, while larger plants may be partially or completely defoliated and checked in growth. (See Pl. VI, A, B; Pls. VII–IX.) Usually the acreage that is destroyed is



SUGAR-BEET FIELD SHOWING INJURY BY BEET LEAF-BEETLE (MONOXIA PUNCTICOLLIS).





OVIPOSITION OF BEET LEAF-BEETLE.

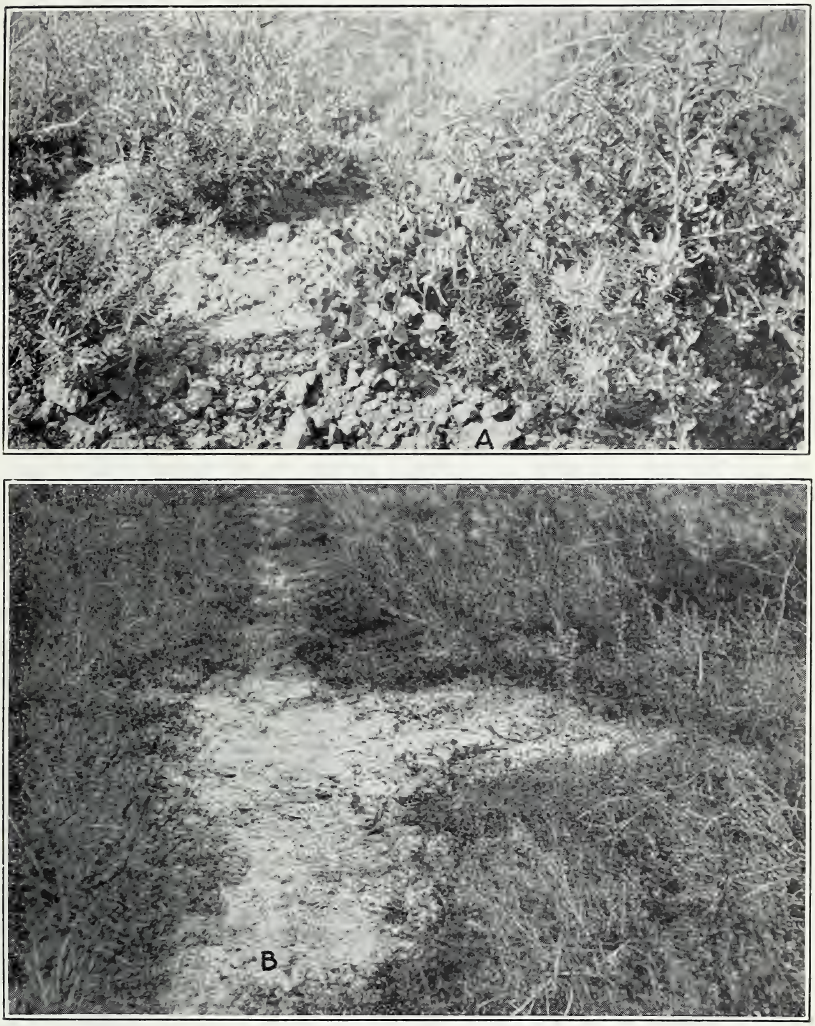
A, Group of dry stems of *Atriplex* sp., a favorite place for egg-laying of beet leaf-beetle (*Monoxia puncticollis*). *B*, Sea-blite plants showing eggs of beet leaf-beetle. *C*, Sugar-beet leaf showing eggs of beetle. About natural size.

HOST PLANTS OF BEET LEAF-BEETLE (MONOXIA PUNCTICOLLIS).

A, *B*, Salt-bush (*Atriplex* sp. and *Atriplex patula*). *C*, Saltwort (*Salsola kali*). *D*, Russian thistle (*Salsola pestifer*).

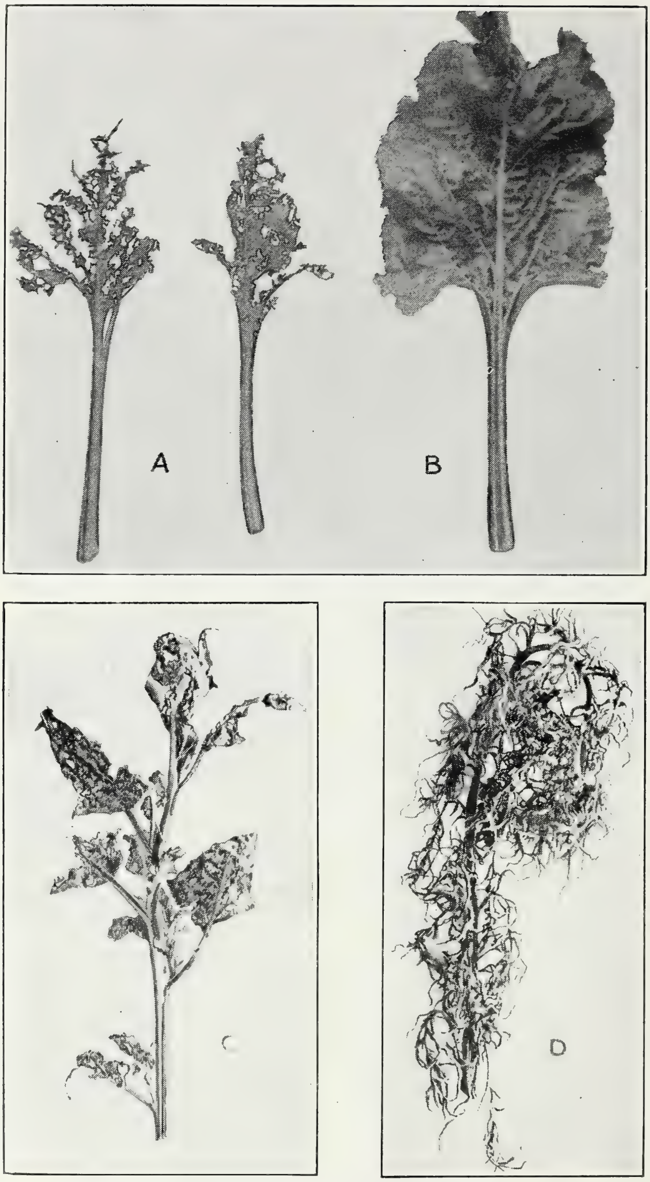
HABITAT OF BEET LEAF-BEETLE.

A, Alkali area overgrown with sea-blite, furnishing natural food for beet leaf-beetle. *B*, Typical alkali area showing grass tufts under which beet leaf-beetle hibernates.



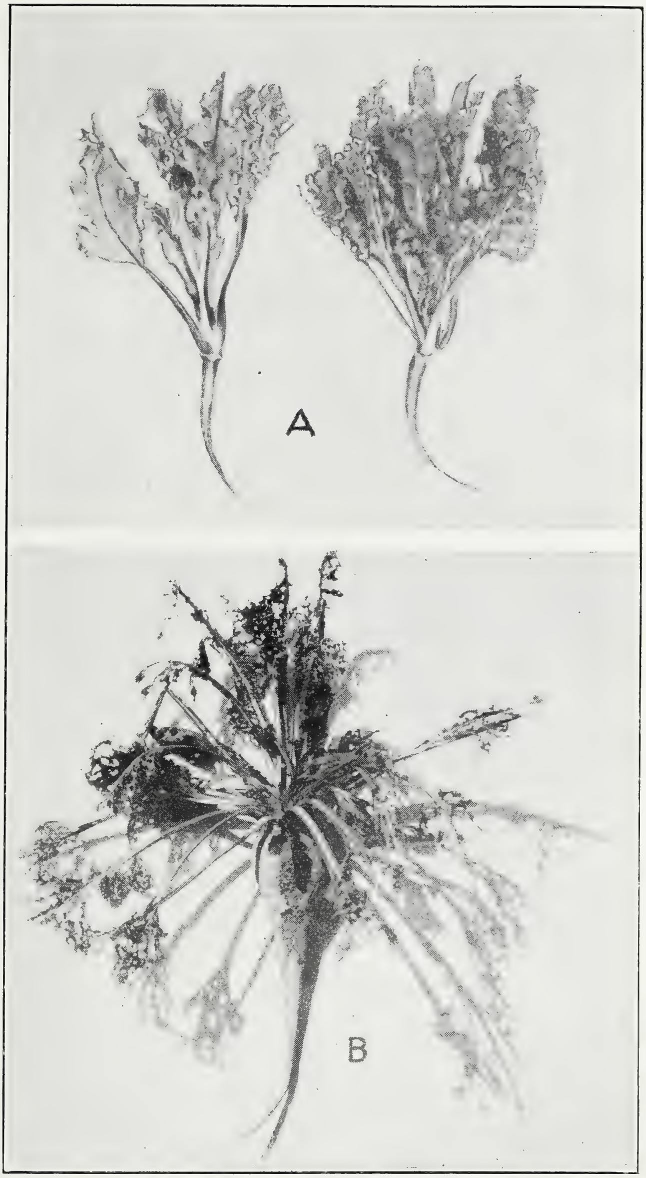
HABITAT OF BEET LEAF-BEETLE.

A, Abundance of eggs found on sea-blite (*Dondia* sp.) and salt-bush (*Atriplex hastata*). *B*, Habitat in alkali flat contiguous to beet fields; bare spot near center is white with alkali.



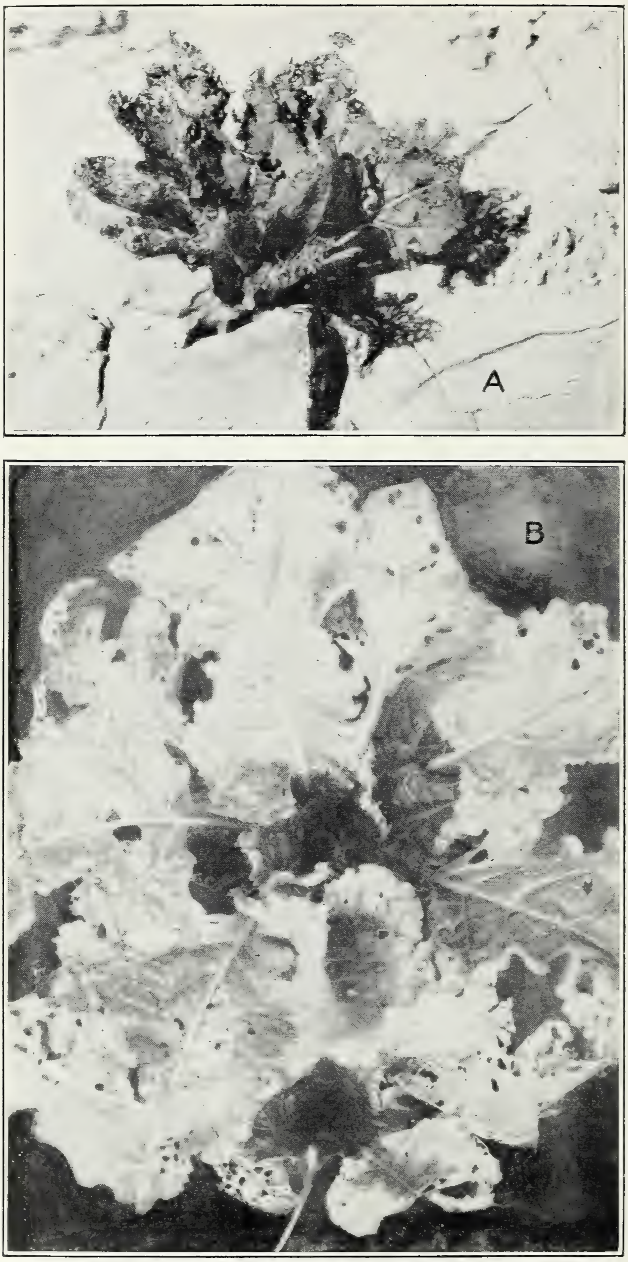
FOOD PLANTS OF BEET LEAF-BEETLE.

A, Sugar-beet leaves riddled by beet leaf-beetle. *B*, A less injured leaf. *C*, Lamb's-quarters killed by larvæ of beet leaf-beetle. *D*, Sea-blite killed by same.



WORK OF BEET LEAF-BEETLE.

A, Small sugar-beet plants riddled by adults of beet leaf-beetle. *B*, Larger plant defoliated by beetles.



WORK OF BEET LEAF-BEETLE.

A, Sugar beet in beet field injured by beet leaf-beetle, all outer leaves riddled. *B*, Sugar-beet top showing injury by beet leaf-beetle around margins of outer leaves.

WORK OF BEET LEAF-BEETLE.

A, Sugar-beet leaf skeletonized by beet leaf-beetle; beetle natural size below. *B*, Sugar-beet seed stems entirely denuded by beet leaf-beetle.

small, although in some years, in 1909 for example, 200 acres of sugar beets in the Arkansas Valley were observed that were literally "wiped out." As a rule, the most noticeable loss resulting from infestation is a reduction in sugar content which follows defoliation. Owing to various other factors which tend to increase or decrease the sugar in the beets, it is impossible to state definitely how much loss may be expected from defoliation by the beet leaf-beetle. Comparative analyses have indicated, however, that injury varying from partial to complete defoliation during August may result in a loss of from 5 to 25 per cent of sugar.

During the summer of 1912 Miss V. W. Pool, of the Bureau of Plant Industry, discovered that the beet leaf-beetle may serve as an agent in distributing the spores of the leaf-spot disease (*Cercospora beticola* Sacc.). July 31 Miss Pool collected four beetles from sugar beets at Rocky Ford and confined them for a few minutes in a culture plate of bean media. One colony of Cercospora developed in this plate.

In feeding on sugar beets the beetles cut large irregular holes (Pl. VIII; Pl. IX, A) through the leaves. The older, outer leaves are preferred, and when riddled the portions between the holes turn brown and fall away, leaving nothing except the petioles and larger veins. As previously mentioned, the insects prefer certain weeds as food, and as a rule spread to the beets when the favorite weeds are scarce or exhausted. As a result the beets growing nearest the weeds are the first to become infested.

The beetles are strong fliers, and during July and August may spread pretty generally over beets growing near alkali areas. A field of beets may be generally infested, but almost invariably there will be certain areas, varying from 6 to 20 or more feet in diameter, where the beetles congregate in large numbers. As many as 200 or 300 beetles may occur on single large beets, and the foliage is naturally more quickly destroyed than on less badly infested plants. As a result these areas are usually conspicuous in infested fields.

The larvæ feed in exposed positions on the upper or lower sides of the leaves. On thick-leaved plants they may eat pits in the leaves without cutting through, but on thin-leaved plants they usually cut irregular holes entirely through the leaves.

When mature the larvæ leave the plants and burrow into the soil to a depth of a half inch to 2 inches and form cells by wriggling about. The soft, yellow pupæ are formed in these cells. The adults develop in the cells and usually remain in them for two or three days. When they emerge they are dull yellow and soft. They commence to feed at once and become hardened and attain full color within a few days.

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LIFE HISTORY.

In the Arkansas Valley of Colorado and in regions having a similar temperature, two full generations or broods and a partial third generation occur each year.

The adult passes through the winter on the surface of the ground on or about the alkali areas, under tufts of grass, heaps of dead weeds, and other rubbish. The favorite location for hibernation is under tufts of "tickle grass" (*Panicum capillare*), which occur abundantly on alkali areas (Pls. IV, V). Under natural conditions the majority of the beetles will congregate for hibernation under grass tufts or under weeds on these areas, a habit of which we may take advantage in controlling the beetles as will be explained later on.

The beetles issue from hibernation during March and early April, the exact time depending on temperature. The earliest date of emergence noted at Rocky Ford, Colo., was March 12 and the latest April 10. Usually the majority of beetles issue during the last days of March and the first days of April. The time of emergence corresponds with the appearance of young Russian thistles, sea-blite, and lamb's-quarters. On these plants the beetles feed and mate and within a short time commence to deposit eggs (Pl. II). The first eggs may be laid during the last days of March and through April, but ordinarily the bulk of the eggs is not deposited until the latter part of April or in May. The development of the first eggs and larvæ is slow. Under ordinary conditions the majority of the beetles of the first generation develop between the last days of May and the middle of June.

The beetles of this generation usually feed for 10 days or two weeks and then deposit eggs for the second generation. The bulk of the eggs is deposited during the latter part of June and through July and the majority of the beetles develop during the latter part of July and early August. During the remainder of the summer the beetles occupy the greater portion of their time in feeding. A few eggs are usually deposited from which the beetles of a partial third generation develop in September or the first days of October. As a rule, the number of beetles of the third generation is small and of slight importance, although occasionally a considerable number may develop about the middle of September.

In general, reproduction occurs from the last days of March until the first days of October, with the period of greatest development between the middle of May and the middle of August.

During September and early October the beetles leave their food plants and go into hibernation. As a rule, the greatest number begin hibernation between September 10 and 20. During bright sunny

days in September hundreds of the beetles may be seen flying from the beet fields in search of hibernating quarters, which they usually succeed in finding before the first severe frosts.

Practically all overwintered beetles die during the latter part of May or in June, although occasional individuals may live until the first days of July, from which it may be seen that the beetles of the first generation live a full year.

REARING RECORDS.

April 6 a mating pair of overwintered beetles was placed in a rearing cage containing growing plants of *Dondia erecta*, one of the sea-blites. The first eggs were deposited April 9. A second cluster of eggs was deposited April 11. The record is as follows:

First generation.

April 6	Beetles collected.
April 11	Eggs deposited.
April 29	Larvæ hatched.
May 23	Larvæ reached maturity.
May 28	First pupæ formed.
June 6	First adults developed.

From the foregoing record the developmental periods are as follows:

	Days.
Egg period	18
Larval period	29
Pupal period	9
Total period from egg to adult	56

The beetles which issued June 6 were placed in a separate cage and supplied with lamb's-quarters (*Chenopodium album*) as food. The record is as follows:

Second generation.

June 6	Beetles developed.
June 17	First eggs deposited.
June 25	First larvæ hatched.
July 9	First larvæ reached maturity.
July 14	First pupæ formed.
July 22	First adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period	8
Larval period	19
Pupal period	8
Total period from egg to adult	35

The beetles of the second generation, as well as those of the first, fed heartily throughout the remainder of the season on the foliage

of sugar beet and lamb's-quarters, but no eggs for a third generation were deposited. All went into hibernation before the middle of September.

The dates of emergence and other dates given in the foregoing records tally almost to a day with those made in independent field records during another season.

Every year a few beetles of a partial third generation are produced. This is shown by the following records:

On May 17 several large larvæ were collected in the field from lamb's-quarters and placed in a rearing cage.

First generation.

May 17	Larvæ collected.
May 19	Larvæ reached maturity.
May 23	First pupæ formed.
May 30	First adults developed.

As the larvæ were collected in the field, the foregoing record is not complete. The pupal period, however, was 7 days. A pair of these beetles mated June 14 and were placed in a separate cage. The record is as follows:

Second Generation.

May 30	Beetles developed.
June 14	Beetles mated.
July 11	First eggs deposited.
July 20	First larvæ hatched.
July 29	First larvæ reached maturity.
August 3	First pupæ formed.
August 12	First adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period	9
Larval period	14
Pupal period	9
Total period from egg to adult	32

The beetles, 15 in number, which developed August 3 were confined in one cage. August 21 a single cluster of 17 eggs was deposited but none thereafter, and all the beetles went into hibernation during early September. The record for these 17 eggs is as follows:

Third generation.

August 12	Beetles developed.
August 21	First eggs deposited.
August 27	Larvæ hatched.
September 10	Larvæ reached maturity.
September 20	First pupæ formed.
October 1	The adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period	6
Larval period	24
Pupal period	11
Total period from egg to adult	41

It will be seen that the adults of the third generation developed October 1. This was considerably later than the date when the majority of the beetles of the first and second generations, both in the field and laboratory, went into hibernation. The beetles of the third generation fed for a day or two and then went into winter quarters.

EGG-LAYING RECORDS.

March 21 several overwintered beetles, which were then on the wing, were captured and confined in a cage with young Russian thistle for food. March 23 a pair of these beetles mated and were placed in a separate cage. By March 29 the female's abdomen was noticeably distended with eggs. The record is as follows:

	Eggs deposited.
April 2	7
April 9	34
April 12	40
April 18	35
April 23	5
May 15	23
May 17	21
May 23	30
June 10	6
June 15	9
June 23	5
Total number of eggs	215

The male died June 25 and the female July 7. These beetles were observed copulating March 23, 25, 26, 27, 31; April 1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 24, 26, 27, 28; May 7, 11, and 13. It is interesting to note that such frequent mating is not necessary to insure the fertility of the eggs. This is demonstrated by the following records:

March 24 a female, with abdomen noticeably distended with eggs, was captured in the field and confined in a cage without a male. Eggs were deposited as follows:

	Eggs deposited.
March 27	33
April 2	4
April 5	6
April 9	25

April 10	29
April 12	20
April 14	15
April 17	30
April 19	29
April 22	35
April 26	9
April 30	31
May 7	22
Total number of eggs deposited	288

This beetle died May 15. As previously noted, she was confined without a mate, but had evidently been impregnated previous to March 24, as all her eggs hatched.

On May 9, 1911, an overwintered female was captured in the field and confined in a cage without a male. Eggs were deposited as follows:

	Eggs deposited.
May 10	14
May 11	18
May 12–14	32
May 15	20
May 16	13
May 17–18	40
May 19	15
May 23	10
May 24	25
May 25	21
May 27	11
May 29	16
May 31	32
June 2	22
June 3	12
June 4	17
June 5	8
June 6–7	58
June 8–9	26
June 10	11
June 12	6
June 14	6
June 19	7
Total number of eggs	440

HISTORY.

The beet leaf-beetle was first described by Thomas Say (*1*) in 1824 under the name of *Galleruca puncticollis*, from Mississippi and Arkansas.

In 1838 Harris (*2, p. 101*) made what is evidently the first mention of the habits of this species, stating, while writing of the striped cucumber beetle,[4] that "the habits are presumed to be the same as those of *Galeruca puncticollis*, which is found in profusion on the common Salsola. The larvæ of this species live in the earth and feed on the roots of Salsola, and do not leave the earth until they become perfect insects." The food plant mentioned is undoubtedly right, but the statement that the larvæ feed on the roots is erroneous and was doubtless inspired by the finding of larvæ prior to pupation in the earth about the roots.

In 1865 (*3*) the species was redescribed under the name of *Galeruca maritima* by LeConte, who stated that it was abundant from New York to Florida.

In 1893 Dr. G. H. Horn (*4*), in his monograph of the Galerucini, redescribed the species, placing it in the genus Monoxia, characterizing the genus and furnishing a list of synonyms and varieties with a consideration of the distribution.

The beet leaf-beetle is a comparatively new pest. The first records of injurious attack to cultivated crops were in 1898. In that year Dr. Wm. P. Headden (*5*) reported that the species had been plentiful on July 3 of 1897, and was doing considerable damage to sugar beet at Fort Collins, Colo. At that date the beets were sprayed with Paris green at the rate of 1 pound to 50 gallons of water, which gave the best results of any insecticide tried. The same year the senior author (*6*) recorded a simultaneous infestation to sugar beet, at Hagerman, N. Mex., in 1897, and gave notes on the insect's habits and history.

In 1900 Messrs. Forbes and Hart (*7, p. 475–476*) gave a brief account of the species in a comprehensive bulletin on the economic entomology of the sugar beet.

In 1902 Prof. C. P. Gillette (*8*) reviewed the previous history of the species and reported attack to sugar beets at Fort Collins, Colo., giving notes on the insect's life history and habits as it occurred in that region. It is recommended that in order to prevent injury to beets, alkali ground be avoided for planting purposes. This account is illustrated by a plate showing the eggs, larvæ, beetle, and injury.

In 1903 the senior author (*9*) published some additional notes in regard to this species, reporting injury to beets at Rocky Ford, Colo., in 1902, and furnishing descriptions of the egg and of the larva, with original illustrations of these and of the beetle. The same year he (*10; 11, p. 9–11*) published a summarized account of the species, followed by a condensed report (*12*).

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[4] *Diabrotica vittata* Fab.

In 1906 Prof. R. A. Cooley (*13*) mentioned attack to beets at Billings, Mont.

In 1912 and in 1918 summarized popular economic accounts were published by Messrs. Sanderson (*14, p. 337–339*) and Crosby and Leonard (*15, p. 95–96*).

NATURAL ENEMIES.

LADYBIRD BEETLES.

Fortunately the beet leaf-beetle has a goodly number of natural enemies. Among the most useful are the convergent ladybird (*Hippodamia convergens* Guér.), the sinuate ladybird (*H. sinuata* Muls.), and the glacial ladybird (*H. glacialis* Fab.). These ladybird beetles do considerable good by destroying the eggs of the overwintered leaf-beetles. Occasionally the ladybirds nearly " wipe out " the eggs which are deposited on certain areas during April and May. A case of this kind was noted during the spring of 1911. On a neglected spot of alkali soil about an acre and a half in extent which had been undisturbed for three years and was covered with a rank growth of "tickle grass" and weeds, the leaf-beetles had hibernated in large numbers. With the advent of warm weather the following spring an abundant supply of Russian thistle, lambs'-quarters, sea purslane, and sea-blite sprang up and the conditions promised to be ideal for the production of an enormous first generation of the beet leaf-beetle. As soon, however, as egg laying began, the ladybirds began their good work, continuing it through April and May and into June, or until the majority of the overwintered beetles had died or scattered to other quarters. Only a very few leaf-beetle larvæ of the first generation developed on this area.

As previously noted, the beet leaf-beetle hibernates on comparatively restricted areas. The ladybirds, however, enjoy a much wider range and hibernate under weeds, grasses, yucca plants, and rubbish wherever convenient shelter is found. Being thus widely scattered, it frequently happens that the ladybirds occur in comparatively small numbers on the areas where the leaf-beetles are ovipositing, and there are always some eggs which escape destruction.

The ladybirds eat the eggs of the beet leaf-beetle practically throughout the season but by far the greater number are destroyed during the spring at a time when aphids and other soft-bodied insects are less plentiful. The ladybirds simply utilize the leaf-beetle eggs as a convenient supply to tide them over from the time of emergence from hibernation until aphids become abundant, which is not strange, as the leaf-beetle eggs have tough shells and are consequently more difficult to eat than aphids.

The ladybirds occasionally destroy newly hatched leaf-beetle larvæ. On the other hand, the ladybird larvæ apparently relish the young larvæ of the leaf-beetles but seldom eat the eggs.

PENTATOMID BUG.

The nymphs and adults of the pentatomid bug *Perillus bioculatus* Fab. var. *claudus* Say feed on the larvæ of the leaf-beetle and the adults also feed on the beetles. The eggs of this bug are of the usual pentatomid type and are deposited in clusters on plants among the eggs of its host. More than one generation is evidently produced annually, although the bugs are rarely abundant enough to reduce the leaf-beetles noticeably. The adult bugs pass through the winter under tufts of grass, frequently among the hibernating leaf-beetles. One generation was under observation at Rocky Ford, Colo. May 1 a female bug was confined in a cage with leaf-beetle larvæ as food. May 7 she deposited a cluster of 17 eggs. The record is as follows:

May 7	Eggs deposited.
May 19	Eggs hatched.
May 25	First molt.
May 30	Second molt.
June 2	Third molt.
June 5	Fourth molt.
June 11	Fifth molt.

The periods of the egg and nymphal stages or instars are as follows:

	Days.
Egg stage	12
First nymph stage	6
Second nymph stage	5
Third nymph stage	3
Fourth nymph stage	3
Fifth nymph stage	6
Total	35

A single species of internal parasite was reared, a tachina fly, *Hypostena* sp.[5] This fly is rare and few were reared. It seems remarkable that the larvæ of this, as well as of other leaf-beetles, are not more commonly parasitized since they are of good size and feed in exposed positions where they apparently offer an "easy mark" for parasites.

MITE AND SPIDER.

During the latter part of July, 1911, a few large, red larvæ of a mite, *Trombidium* sp. near *muscarum*, were found clinging to the abdomens of a few beetles. They were of rare occurrence and apparently caused the infested beetles no damage.

[5] Identified by Mr. W. R. Walton.

A large red spider, *Phidippus coloradensis* Thorell, was unintentionally confined with several beetles. This spider seized a beetle and devoured it.

CANNIBALISM.

Occasionally, both in the field and in confinement, nearly full-grown larvæ have been found feeding on the eggs of their own species. This curious habit, however, is not common.

FUNGUS DISEASE.

September 4, 1909, a fungus disease, *Botrytis bassiana* Bals., was found attacking the larvæ at Rocky Ford, Colo. The diseased larvæ were in pupation cells in a small area of moist soil in the corner of a beet field. Twenty per cent of the larvæ in this area were dead and covered with fungus, but very few pupæ were affected. Since this disease was not observed in after years, it is evidently too rare to be of material benefit.

TOADS.

Common toads eat the adult leaf-beetle but have not been found in sufficient numbers on the infested areas to reduce the number of the beetles materially. A medium-sized toad was taken from a badly infested patch of sea-blite and dissected. The stomach contained 39 of the beet leaf-beetle adults, a convergent ladybird (*Hippodamia convergens* Guér.), a grasshopper, and several ants, ground-beetles (Carabidae), and click-beetles (Elateridae).

POULTRY AND WILD BIRDS.

Chickens feed on the beetles readily and under certain conditions may be utilized as a means of controlling this leaf-beetle. This is demonstrated by the following experiment: On one occasion a flock of chickens was turned into a badly infested field of beets at Rocky Ford. That evening a chicken was killed and 431 beetles and a few larvæ were taken from the crop. The chickens were allowed to remain among the beets and two weeks later another bird was killed. The crop contained 250 beetles.

The Bureau of Biological Survey has found specimens of the beet leaf-beetle in the stomachs of the starling (*Sturnus vulgaris*) and prairie chicken (*Tympanuchus americanus*) and of other species of the genus Monoxia in the stomachs of the northern and Wilson's phalaropes (*Lobipes lobatus and Steganopus tricolor*), least flycatcher (*Empidonax minimus*), English and vesper sparrows (*Passer domesticus and Poœcetes gramineus*), violet-green swallow (*Tachycineta thalassina*), and pipit (*Anthus rubescens*).

January 23, 1912, a flicker (*Colaptes auratus*) was observed scratching in a tuft of grass under which a number of beetles were in hibernation, but there was no positive evidence that the bird ate any of the beetles.

Flocks of blackbirds frequently congregate in fields of beets which are strongly infested by the beet leaf-beetles. August 17, two such birds were shot, but their crops were found to contain nothing except vegetable matter. No noticeable reduction in the number of the beetles could be observed during times when blackbirds frequented the fields, and it may be concluded that they do not normally feed on these insects.

OTHER CHECKS.

Occasionally cattle or horses are turned on to areas where the beetles are in hibernation, and a few beetles may be trampled upon and killed, but as a rule few are destroyed in this way.

Ordinarily this insect is not greatly affected by climatic conditions. Remarkably few hibernating beetles die during the winter. During January of one year a low spot upon which many beetles were in hibernation was flooded to a depth of 3 or 4 inches by melting snow. The majority of the beetles saved themselves by climbing up the grass stems above the water. On this area there were a few tufts of grass which were covered with a crust of snow, and here the beetles were trapped under the crust, and were drowned; but this case of winter killing is exceptional, and usually the beetles are uninjured by rain, snow, or cold.

Some of the eggs which are deposited early in the spring, when the nights are still frosty, become cracked and fail to hatch. Possibly this is caused by the cold, as no cracked eggs have been found during warm weather. In early spring young larvæ are occasionally knocked from their food plants, and killed by the cold dashing rains, but the number destroyed in this way is usually very small.

EXPERIMENTS WITH INSECTICIDES.

The following insecticides were tested against the beet leaf-beetle at Rocky Ford, Colo.:

Spraying experiments.

No. 1. Paris green, 1 pound to 50 gallons of water.
No. 2. Paris green, 1 pound, and whale-oil soap, 3 pounds, to 50 gallons.
No. 3. Paris green, 1 pound, and rosin-fish-oil soap, 3 pounds, to 50 gallons.
No. 4. Paris green, 1 pound, and laundry soap, 2 pounds, to 50 gallons.
No. 5. Paris green, 1 pound, and lime, 1 pound, to 50 gallons.
No. 6. Paris green, 1½ pounds to 50 gallons.
No. 7. Paris green, 1½ pounds, and whale-oil soap, 3 pounds, to 50 gallons.
No. 8. Paris green, 1½ pounds, and whale-oil soap, 3 pounds, to 50 gallons.

No. 9. Paris green, 2 pounds, and whale-oil soap, 3 pounds, to 50 gallons.

No. 10. Arsenate of lead, 3 pounds, and laundry soap, 3 pounds, to 50 gallons.

No. 11. Arsenate of lead, 3 pounds, and Paris green, ½ pound, to 50 gallons.

No. 12. Arsenate of lead, 5 pounds to 50 gallons.

No. 13. Arsenate of lead, 5 pounds, and Paris green, 1 pound, to 50 gallons.

No. 14. Arsenate of lead, 5 pounds, and lime-sulphur solution, 2 gallons, to 50 gallons.

No. 15. Zinc arsenite, 2½ pounds, and Paris green, ½ pound, to 50 gallons.

No. 16. Zinc arsenite, 2 pounds, and whale-oil soap, 3 pounds, to 50 gallons.

No. 17. Zinc arsenite, 2½ pounds, and whale-oil soap, 2½ pounds, to 50 gallons.

Dusting experiments.

No. 18. Paris green, 1 pound to 50 pounds of flour.

No. 19. Paris green, 2 pounds to 50 pounds of flour.

No. 20. Paris green, 5 pounds to 50 pounds of flour.

No. 21. Paris green, 1 pound to 50 pounds of wood ashes.

No. 22. Paris green, 2 pounds to 50 pounds of wood ashes.

Several additional experiments were made, especially with lead chromate at rates varying from about ½ pound to 3 pounds in 50 gallons of water, but this substance proved to be utterly worthless either as a stomach poison or as a repellent against this insect. The same is true in its application against most other forms of insect pests.

In the course of these experiments more than 60 acres of sugar beets were sprayed or dusted. With the spraying experiments preliminary tests were made with knapsack sprayers, and the poisons which gave promise of being successful were later tried out on a larger scale with field sprayers. The "dust" was applied with a "powder gun" or was shaken upon the foliage from cheesecloth sacks.

Without exception the poisons tested in the foregoing experiments proved unsatisfactory against the adults but in most cases were partially or wholly effective against the larvæ. The failure to control the beetles was due to the fact that, as a rule, they refused to eat the poisoned foliage except when no other food was available. All the poisons, except lead chromate, killed the beetles whenever eaten. Usually, however, the beetles promptly deserted the treated plants but returned after the poison was washed away or blown from the foliage or after new leaves developed. The poisons were usually effective as repellents for periods of from 2 to 5 days.

The poisons with which whale-oil soap or lime-sulphur solution were used served as repellents for longer periods than when applied

alone. The benefits derived from the repellent effect were, however, usually of little importance.

Paris green, whenever eaten by the beetles, proved somewhat quicker in its killing effect than either arsenate of lead or zinc arsenite. Paris green, 1 pound to 50 gallons of water, gave more promising results than any other mixture. When applied thoroughly to the upper and lower surfaces of the leaves a fairly good number of beetles were killed but when applied to the upper surface the results were entirely unsatisfactory. In one experiment at the foregoing strength a large number of beetles, which had recently emerged from their cells and were too soft to fly, crawled to the sprayed beets and were promptly killed. Such instances as this, however, are exceptional. As a rule the newly-developed beetles feed upon weeds until they become hardened and then fly to the beets. When they are able to fly the majority almost invariably desert or avoid sprayed or dusted plants. Even in exceptional cases when the beetles are killed, others usually take their places promptly, and unless frequent applications of the poison are made the results are of little benefit. In one experiment 20 acres of beets were sprayed twice and in another 5 acres were sprayed three times, but the results were only temporary and did not justify the expense.

In dusting experiments the majority of the beetles refused to eat the treated foliage and few were killed. The "dust" served as a repellent for a few days but this protection was too brief to be of practical benefit.

The larvæ are readily killed with Paris green but they seldom occur in sufficient number on sugar beets to make it profitable to spray for them alone. The weeds, upon which the bulk of the larvæ normally develop, are usually scattered about in inaccessible places and it is somewhat doubtful if they could be profitably sprayed, except in cases of severe outbreaks of this insect.

RECOMMENDATIONS FOR CONTROL.

Basing an opinion on the experiments and observations which were conducted in the Arkansas Valley of Colorado during four seasons, it may be concluded that arsenicals can not be entirely depended upon as a practical means of controlling the beet leaf-beetle.

As previously mentioned, the majority of the beetles congregate, during the fall, on or about alkali areas. Here they hibernate on the surface of the ground, under tufts of grass, heaps of weeds, or other shelter. The most effective and practical method of control is, therefore, to destroy the beetles in their hibernating quarters. This may be accomplished easily and cheaply between the middle of November and the first of March, by burning the dead grass and weeds.

The beetles may be trapped by placing heaps of weeds, or bundles of straw or hay, on or near the alkali areas. It is advisable to place such "traps" not later than August, so that they may become well settled before the beetles seek them for winter quarters. After the beetles have gone into hibernation under the "traps" they may be destroyed by burning.

The effectiveness of burning depends upon the thoroughness with which the beetles and their hibernating quarters are destroyed. Careless, slipshod work will invariably fail to produce the desired results.

Occasionally an infested field is so situated that a flock of chickens may be quartered in it. Chickens relish the beetles, and may be depended upon to do good work in reducing infestation.

The almost invariable failures which have followed the efforts to control the beet leaf-beetle with insecticides have had a tendency to discourage the beet growers, and many regard the injuries inflicted by this pest with indifference or as an unavoidable evil.

The results of the investigations which are here reported will serve to clear up many hitherto unpublished facts regarding this insect. Among others the practically complete knowledge of the insect's life history shows that this pest can be controlled by simple and inexpensive means. The destruction of the beetles by burning them in their hibernating quarters has proved so thoroughly effective and so easily accomplished that there is little or no excuse for beet growers to continue to submit to injury from this insect in the future.

SUMMARY.

In the Rocky Mountain States sugar beets and garden or table beets, Swiss chard, and spinach are subject to attack by the beet leaf-beetle (*Monoxia puncticollis* Say), or "alkali bug," an insect resembling the elm leaf-beetle.

This insect normally lives in alkali regions, breeding on such weeds as the sea-blites, Russian thistle, salt-bush, and lamb's-quarters, but when it becomes abundant there is an overflow to cultivated plants, which are attacked and often greatly injured.

Injury is accomplished chiefly by the larvæ, although the beetles also do much damage, not infrequently eating young beets "down to the ground." Many hundreds of acres of beets are destroyed every year. The beetles also act as carriers of a fungus disease.

The beetles issue from their winter quarters during March and April, feed on weeds, mate, and within a short time begin laying their eggs. The rounded oval, orange-yellow eggs are laid on the underside of the leaves in masses of varying number, from 2 or 3 to 50, a single female depositing between 300 and 400 eggs and even

more. These hatch in from 8 to 18 days, depending upon the temperature, and the larvæ complete their growth in from 14 to 29 days.

The larvæ feed in exposed positions on either the upper or lower surface of the leaves, eating holes in them, frequently cutting entirely through the leaf. When mature, the larvæ leave the plants and burrow into the earth to a depth of from half an inch to 2 inches and form cells in which the soft yellow pupæ develop. The pupal period requires 8 or 9 days, and then the beetles emerge.

Two generations and a partial third generation are produced annually in the Arkansas Valley of Colorado, where the species has been studied.

Hibernation is passed as a beetle in alkali areas under tufts of grass, heaps of dead weeds, and other rubbish, and the grower may take advantage of the knowledge of this habit to destroy the beetles in their winter quarters, which has proved an effective and practicable method of control.

The best time for this work is between the middle of November and the first of March, when the dead grass and weeds may be burned. The effectiveness of this method depends on the thoroughness with which the hibernating quarters of the beetles are destroyed.

The use of arsenicals has not been entirely satisfactory in the control of this pest.

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